Climate Modeling/Observation Comparisons: New Approaches

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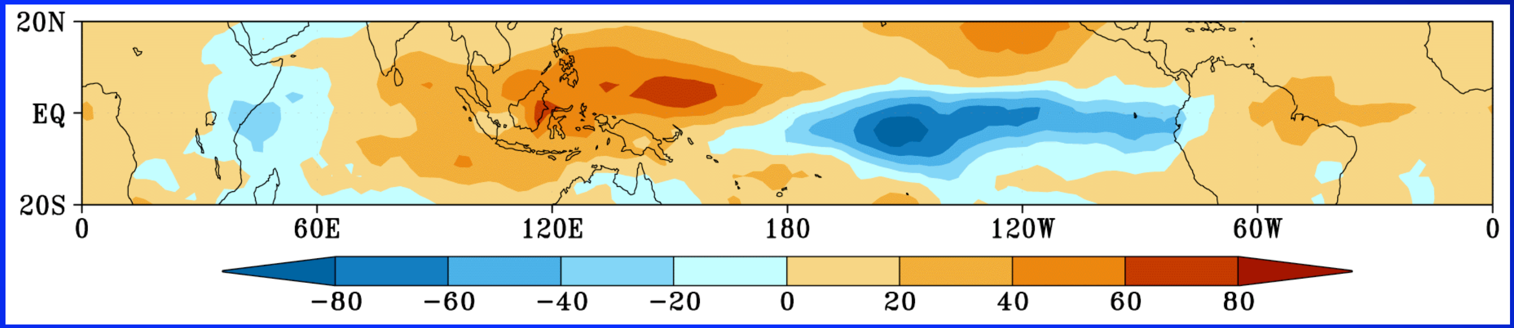
CERES 3rd ST Meeting
GFDL, May 3-5, 2005

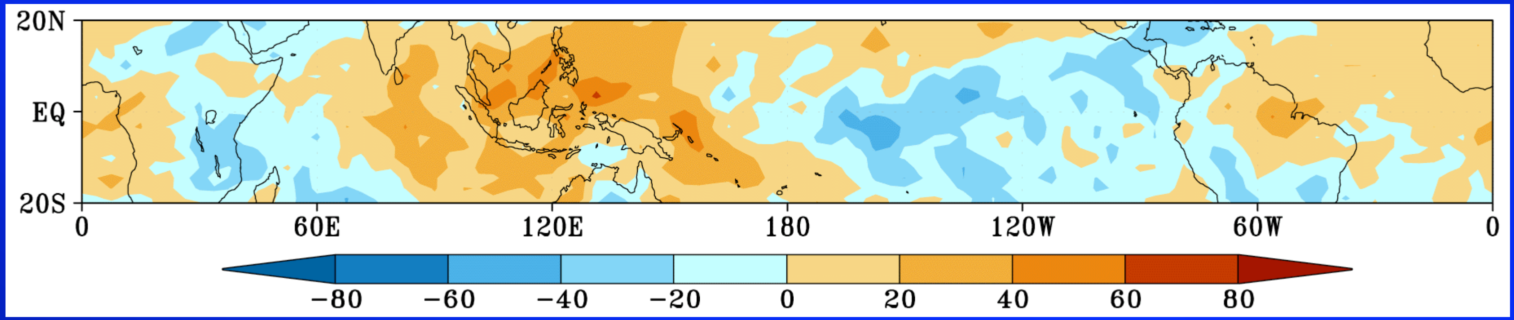
Jan/Feb 98 El Nino TOA LW Flux Anomalies

(relative to ERBE 1985-1989 average)

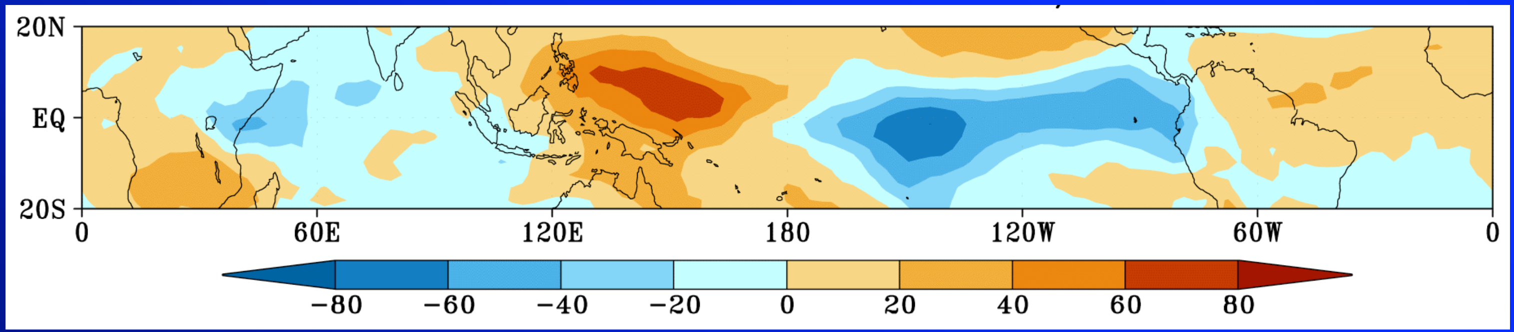
CERES ERBE-Like LW Flux Observations

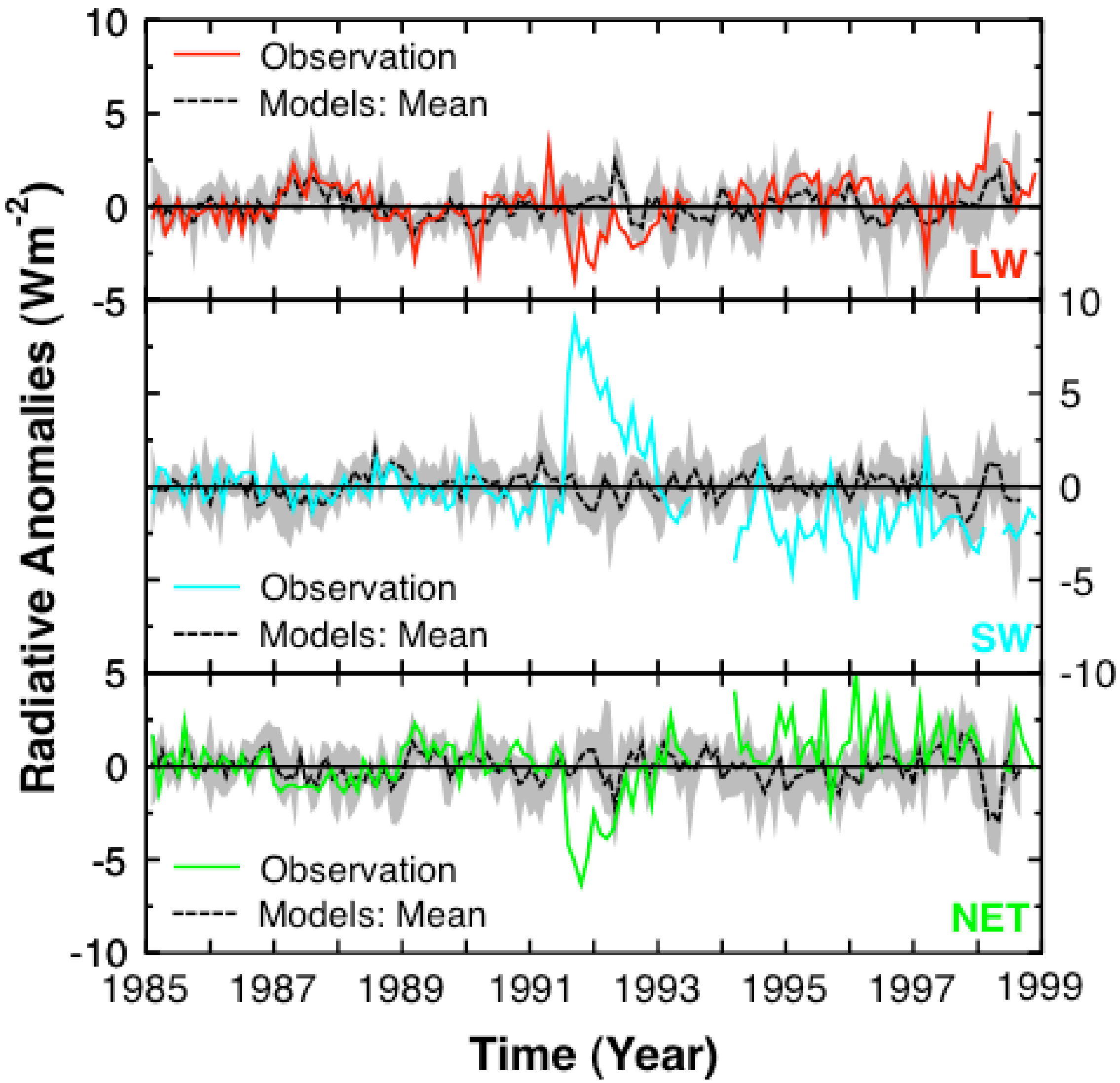


NOAA GFDL Standard Climate Model



NOAA GFDL Experimental Prediction Model

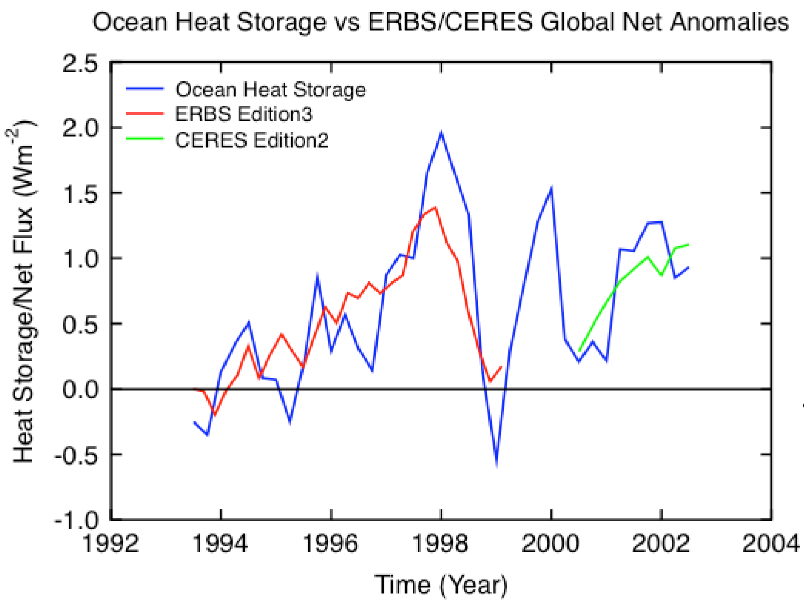




Tropical (20S - 20N) TOA Radiation Anomalies: Observations (color) vs. Climate Models

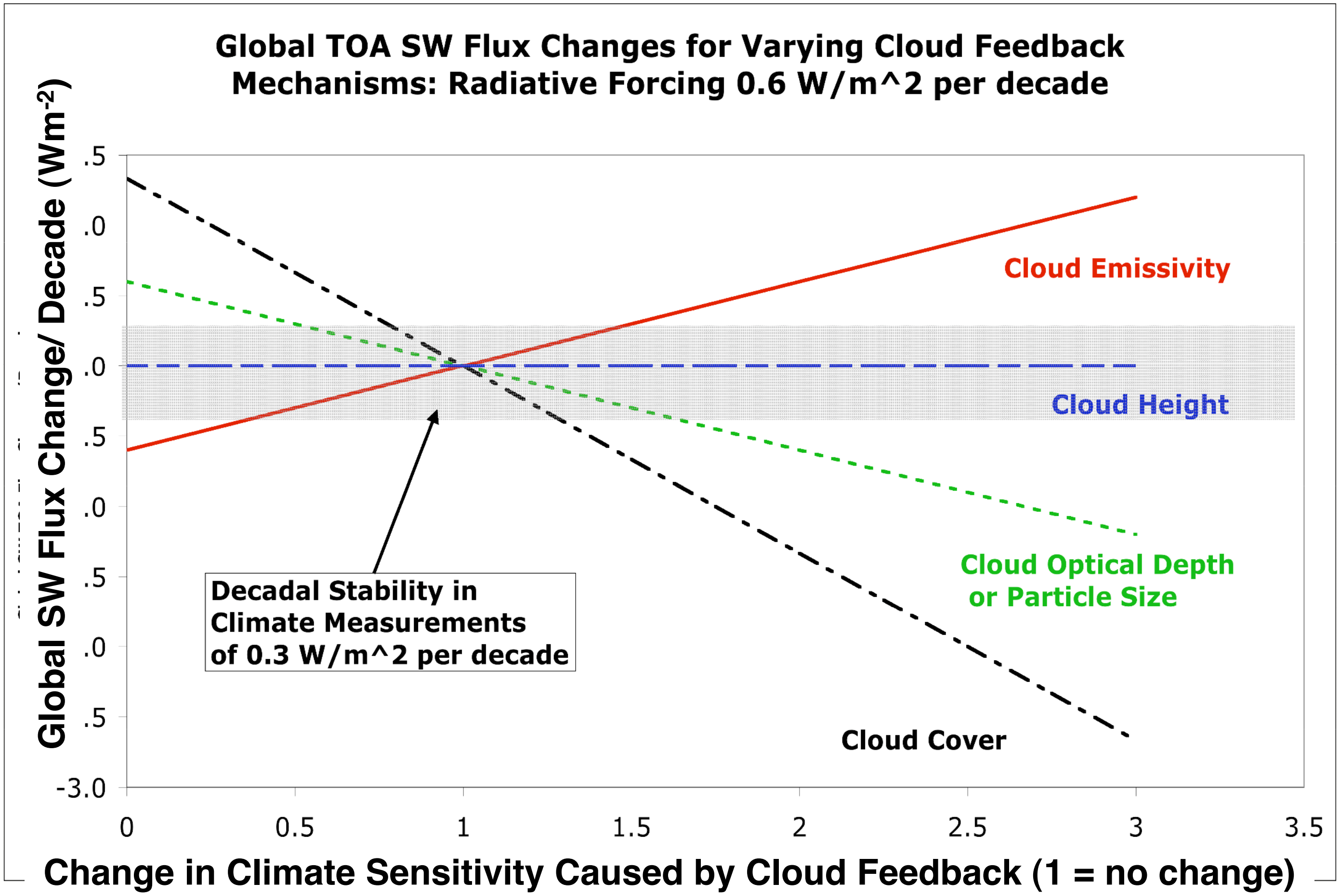
- Climate noise 0.3 Wm^{-2}
- SW reflected lower 90s
- Global dimming recovery?
- Net heating in 90s
- Opposite sign of Iris negative cloud feedback hypothesis
- Surface heating would be 3% in tropical mean precipitation
- Climate models driven with observed SSTs, not Pinatubo
- Pinatubo signal cooling
- Missing cloud feedbacks?
- Natural variability?

Global Radiation and Ocean Heat Storage: What does it mean?



- Climate atmos. noise only 0.3 Wm^{-2}
- Ocean/Rad diff = 0.4 Wm^{-2} 1σ
  = ocean spatial sampling noise
- ERBS cavity radiometer gain change = 0.1% or 0.2 Wm^{-2}
- 1.5 Wm^{-2} variations larger than expected
- IPCC forcing = 0.6 Wm^{-2}/decade
- All other heat storage mechanisms are smaller by factor of 10 or more
- Aerosol/greenhouse forcing changes small except Pinatubo in 91-93
- Large changes = variations in net cloud radiative forcing
- Not clear if ocean => cloud or cloud => ocean
- Non-equilibrium link of ocean/cloud must be unscrambled in model/data

How accurate must measurements be to constrain equilibrium global cloud feedback?



- Regional changes will be larger: but no regional "constraint" and global mean still must be accurately known for global feedback.
- UKMO ensemble climate noise for annual tropical mean SW and LW fluxes ~ 0.3 Wm^{-2}: this might be a reasonable lower limit on accuracy.

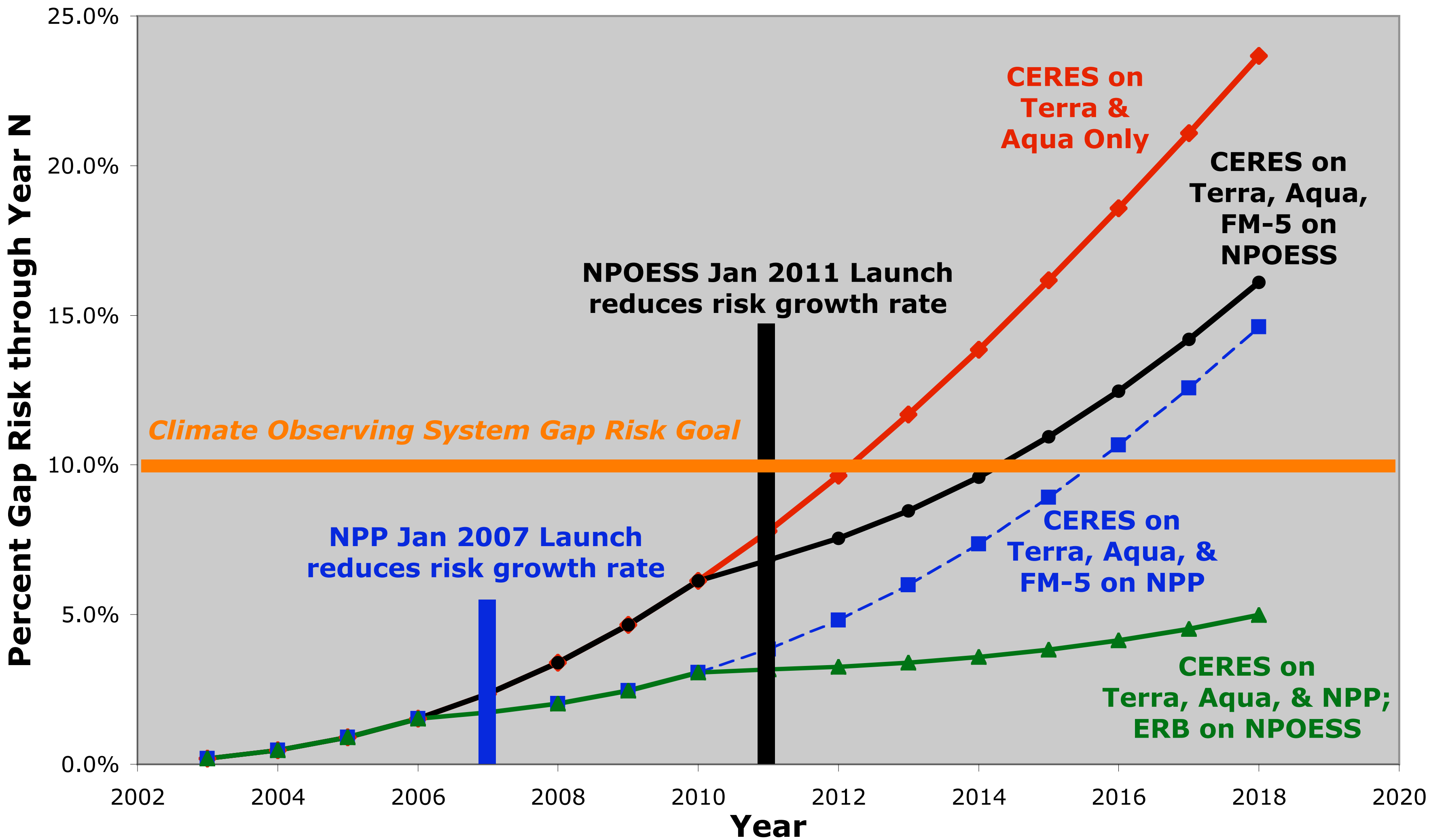
NIST/NASA/NOAA Satellite Calibration Requirements Workshop Report (in press, BAMS, May 2005)

- Overlap critical for stability, decadal signals
- Independent observations the 21st climate observing principle
- Goal for decadal stability: 0.3 Wm^{-2}
  - constrain cloud feedback to +/- 50% for 0.6 Wm^{-2} forcing/decade
  - UKMO ensemble tropical annual noise: 0.3 Wm^{-2}
  - impacts instrument overlap requirements
  - impacts completeness of sampling requirements
- Goal for absolute accuracy: 1 Wm^{-2}
  - absolute accuracy should not be too much worse than stability or second order bias errors can alias into stability change.
  - suggested absolute accuracy be no worse than 10 times stability/decade
- TOA flux goals and Surface flux goals similar: but logic not as clear: surface and latent heat fluxes can compensate.
- Did not deal with less stringent regional: needs further study
- Cloud, aerosol, and other goals also linked to radiative forcing or feedback or response. (see BAMS, May 2005, or NIST, March 2004)

How do we reach 0.3 Wm^{-2} per decade?

- **0.3 Wm^{-2} in net flux change per decade is:**
  - 0.003 change in global cloud fraction
  - 0.2K/decade in global cloud temperature
  - 30m/decade in global cloud height
  - 2% in cloud optical depth
  - 2% water particle size (forcing), 4% ice particle size (feedback)
- **Climate Calibration Observatory**
  - Concept mission for NRC Decadal Survey
  - Reference Transfer radiometers (NIST in orbit, 2 at any time)
  - Large fov (~100km) pointable solar and infrared spectrometers and broadband cavities. allows space/time/angle matches
  - 67 degree inclined orbit to underfly all other satellites
  - Focus on 0.1% linearity, independent calibration sources, solar/lunar stability.
  - Use experience of solar irradiance missions, radiation budget missions, SEAWIFS lunar stability, interferometers, etc.

Radiation Budget Gap Risk: Satellite Scenarios



We should regularly evaluate gap risk for all satellite variables....
For U.S. CERES-like fluxes: Terra, Aqua, NPOESS in 2012 (black line in plot.)

International Radiation Budget Perspective

- CERES on Terra, Aqua, NPOESS starting 2011/2012
- Gap risk in U.S. record is 5% through early NPOESS
- GERB on Meteosat provides an independent measure
- CERES/GERB intercalibration requires use of rotating azimuth plane scan control for CERES to align viewing angles with all 250 GERB detectors.
- CERES/GERB SW intercalibration not yet at 1% goal
- CERES has found ~ 1.5% loss of response over first 4 years when in Rotating Azimuth Scan mode for defining radiation anisotropy distribution. Changing to crosstrack for future routine operations on all instruments. Complete study this summer.
- Megha-Tropique (spelling?) in the future

How can we use observations and climate models to:

determine the uncertainty in climate predictions?

more rigorously determine climate observation requirements?

We are searching for a mapping function:

F(Climate Obs - Model Metrics) = G(Climate Prediction Uncertainty)

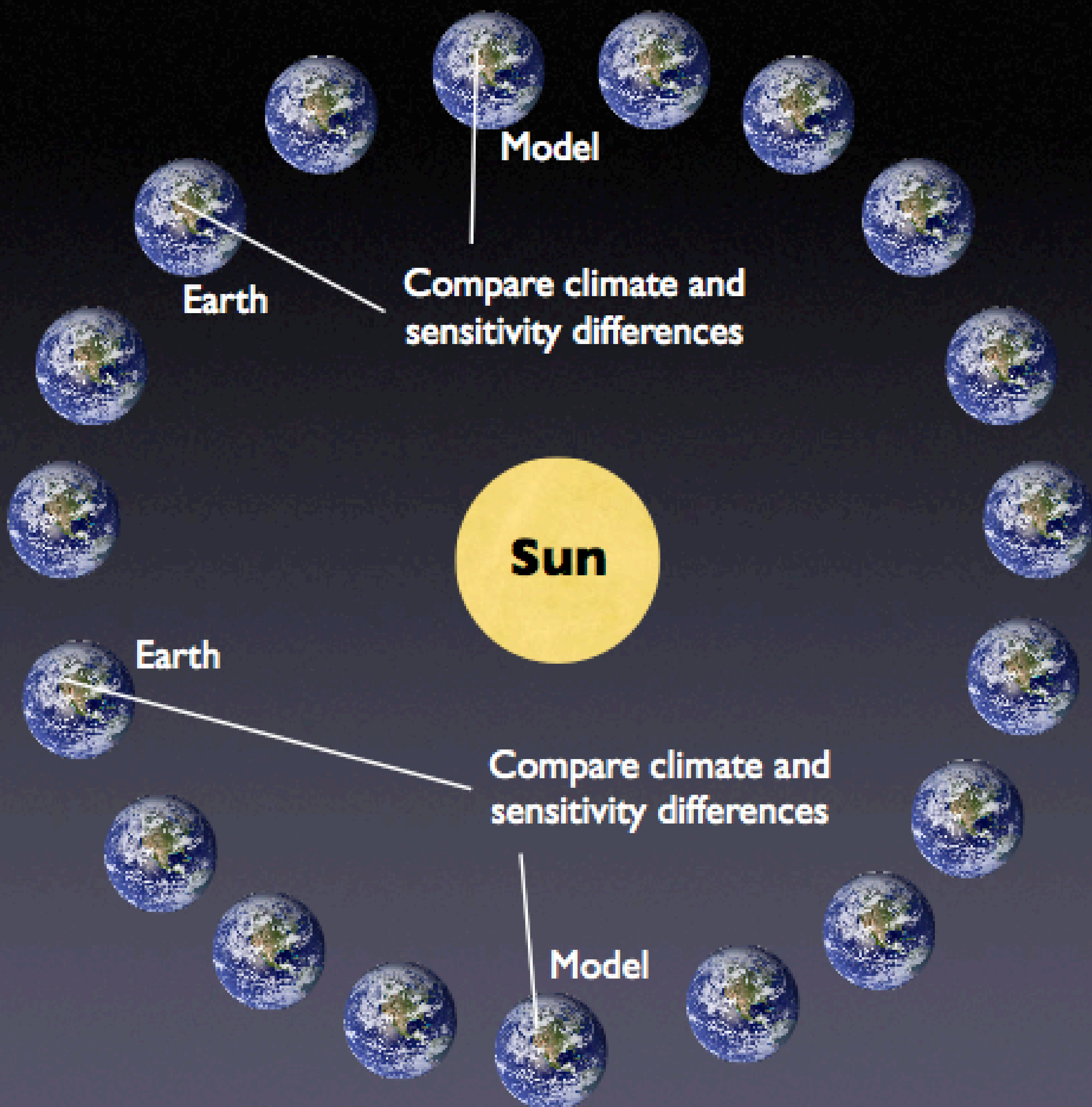
F = Observations minus Models for a range of key variables
at selected time and space scales

- global SST
- seasonal net global cloud radiative effect
- does it take 10? 50? 100?
- nonlinear relationships?

G = Uncertainty in key climate prediction variables/time/space scales.

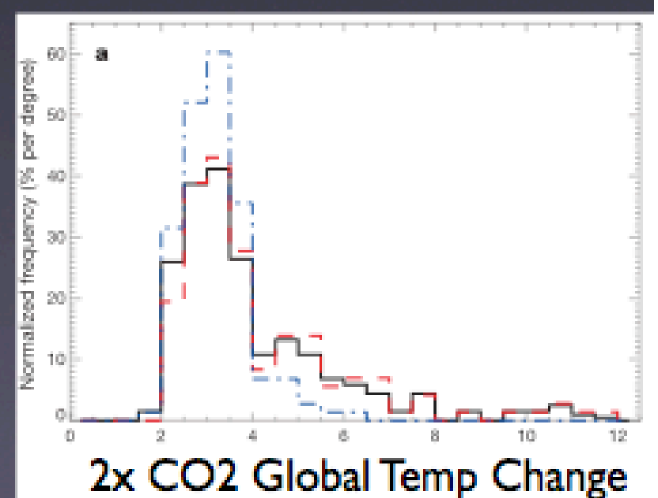
- global mean surface temperature
- summer mean european precipitation
- hurricane frequency

60,000 Earth-Like Planets

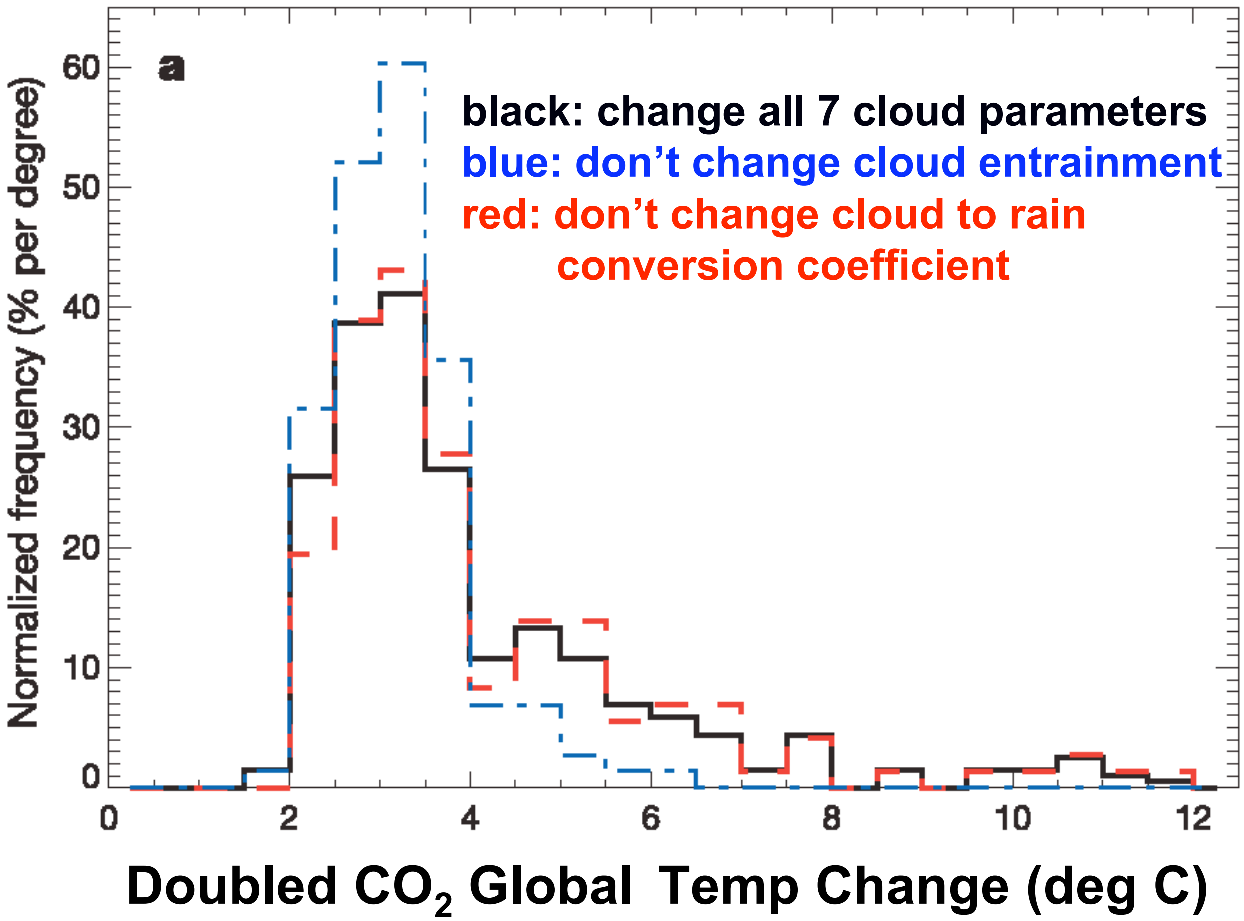


climateprediction.net:
constant known physics
vary uncertain physics
Run for normal CO_2
Run for doubled CO_2

Stainforth et al., 2005, Nature



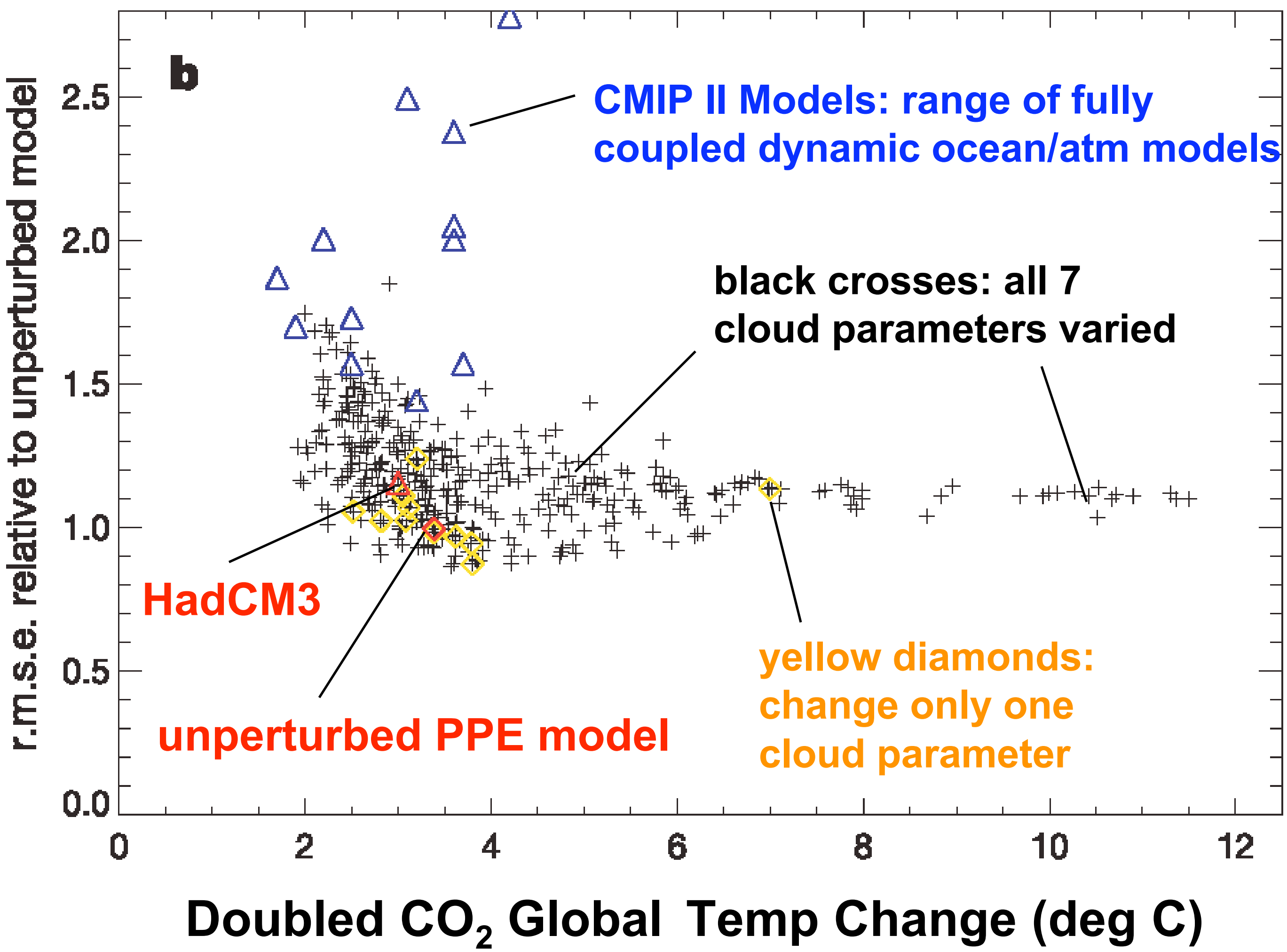
Perturbed Physics Ensemble: Pdf of Climate Sensitivity for Doubling CO_2



Run Characteristics

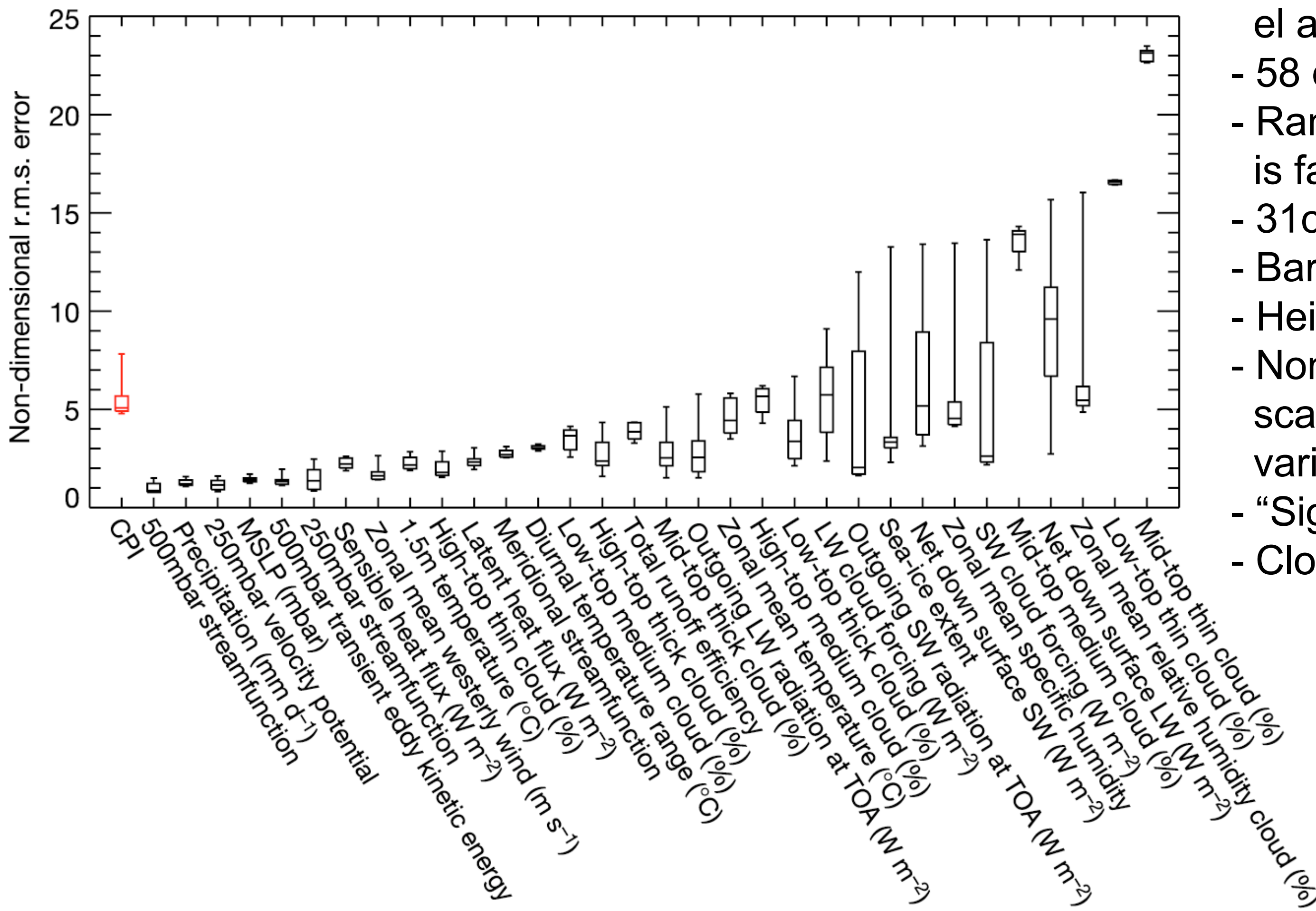
- 2500 runs
- Global Sfc Temp
- Vary 7 cloud and precipitation parameterizations
- note $3^7 = 2187$
- HadAM3 atmosphere
- Mixed Layer Ocn
- Flux Adjust from initial SST run
- last 8 years of 15yr doubled CO_2 runs
- Single 15yr run takes 8 wks on a typical PC

Can we immediately rule out high sensitivity



- rms error vs obs
- scaled to std model
- observations include
  - annual means
  - global maps of
    - surface temp
    - precipitation
    - sea level pressure
    - sensible heat flux
    - latent heat flux
- but no cloud prop or radiation fluxes

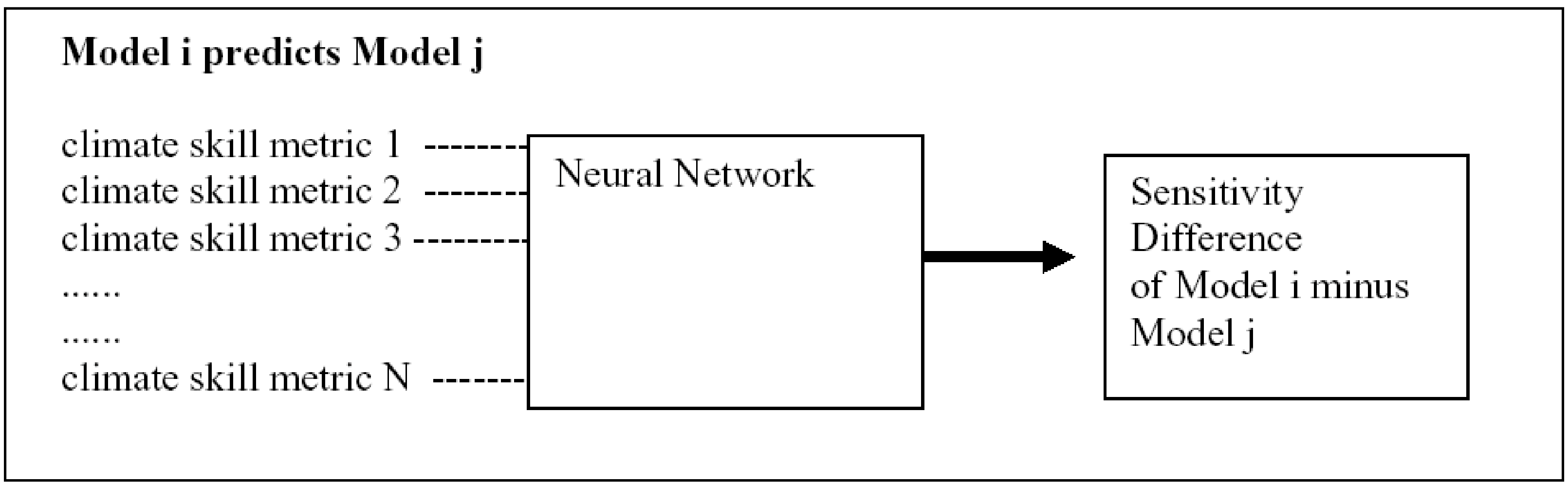
Amount of change for a factor of 6 in climate model sensitivity, by climate variable: clouds dominate



- Results from Murphy el al., Nature, Aug 04
- 58 different climate models
- Range of climate sens. is factor of 5
- 31climate metrics (plot)
- Bars are 25 to 75th pctile
- Height of line is min to max
- Non-dimensional scaling is to interannual variability (noise)
- “Signal to noise”
- Clouds/radiation dominate

Climateprediction.net: 1000s of Perturbed Physics Ensembles using UKMO model with mixed layer ocean.

- From these 1000s of runs, 1000s of different earth-like planets
- For any two model runs, let model i be “Earth” and model “j” be the model
- Climate metrics for “i minus j” = observed minus modeled Earth (no obs error)
- Sensitivity for “i minus j” = climate sensitivity difference and is KNOWN
- Sensitivity not only for global surface temperature: regional summer precip, etc.



Over 1000s of model pairs in the PPE: let the varying model physics show how to optimize the selected climate metrics, and predict uncertainty.
Test robustness comparing other climate models (NCAR, LMD...) and other climate forcings (solar, volcanic, aerosol ...) Test observing system reqmts...

Climate Requirement Steps

- Define accuracy requirements: TOA & Surface Fluxes
  - As a function of time/space scale
  - Absolute/Precision/Stability
  - Independent observations critical (new climate observing sys reqmt)

- Ideal or “Goal” capability
  determine by climate model internal noise variability of mixed layer (atmosphere only) and coupled (ocean/atmosphere) runs

- “Minimum” capability determined by climate forcings and feedbacks as a function of time/space scale

- Climate models are 250km scale, need to use satellite data to show relationship of surface sites to larger time/space scales for sfc site reqmts.

- Long-term goal is to link requirements (variable/time/space) to impact on constraints for climate prediction (e.g. climate metrics tested using climate prediction.net style large ensembles

Summary

- Cloud/Aerosol/Radiation Climate Requirements are very tight
- Independent observations will be key to verify surprises: a missing climate observation principle (21st?)
- We can set observation goals based on:
  - expected global radiative forcing per decade
  - expected global feedbacks and responses per decade
  - climate model estimates of internal climate system noise
- We can consider new calibration concepts like the Climate Calibration Observatory: orbiting reference spectrometers/cavities
- We urgently need more rigorous uncertainty estimates for climate predictions and for climate observation requirements:
  - mapping functions of climate model “error” to prediction uncertainty
  - need for complete set of climate variables, time/space scales

Backup Slides

What about global net fluxes?

- ERBE was about 5 Wm^{-2} (heating) and was within its accuracy bound given calibration, angular sampling, and time sampling limitations
- CERES is reducing all major error sources and has a target uncertainty of about +/- 2 Wm^{-2} in global net.

	SW	LW
– calibration (absolute accuracy)	+/- 1.0	+/- 1.0
– spectral correction	+/- 0.1	+/- 0.1
– spatial sampling	0	0
– angle sampling (new ADMs)	+ 0.5	- 0.1
– improved reference altitude (20km)	+/- 0.1	+/- 0.2
– twilight shortwave flux (adds 0.25)	+ 0.1	0
– spherical earth near sunset/sunrise	< + 0.7	0
– cloud optical depth biases (solar zenith albedo)	+ 0.7	0
– new solar constant (1361 vs 1365)	+ 1.0	0
– time sampling (geo calibration aliasing)	+/- 0.4	+/- 0.1
– ocean heat storage constraint (2000/2001)	0.3 to 1.0	
– expected range in current SRBAVG product global net for 2000/2001:	2 to 6 Wm^{-2}	

What about global net fluxes?

- Ocean Heat Storage variability:
  - Recent submitted paper on merged in-situ/altimeter heat storage for 1992 to mid-2002.
  - Interannual variations: 1 +/- 2.5 Wm^{-2} global mean
  - Single year annual sampling noise: 1.3 Wm^{-2} 1-sigma
  - 10 year average sampling noise: 0.2 Wm^{-2} 1-sigma
  - Completion of ARGO should cut errors in half (southern oceans)

- What is CERES interannual uncertainty in net flux year to year?
  - Calibration stability dominated: ~ 0.1 to 0.2 Wm^{-2}.
  - Global annual net Terra ERBE-Like first 3 years:

Time Period	TOA Net	In-situ/Altimeter	Altimeter
Mar 2000 - Feb 2001:	3.95	-1.4	1.5
Mar 2001 - Feb 2002:	4.69	2.1	1.2
Mar 2002 - Feb 2003:	4.93		